HIGHLY MIGRATORY SPECIES MANAGEMENT TEAM REPORT ON DRIFT GILLNET PERFORMANCE METRICS REVIEW

At the September 2018 meeting, the Council adopted a motion to re-evaluate performance metrics for the large-mesh drift gillnet (DGN) fishery using the regression tree method to estimate bycatch in the fishery as described in Carretta et al. (2017). At the March 2019 Council meeting, the HMSMT provided an update on efforts to adapt the regression tree method to produce bycatch estimates for finfish, comparable to those which are already produced for non-finfish species by scientists in the Southwest Fisheries Science Center's (SWFSC) Marine Mammal and Turtle Division (MMTD). The Council directed the HMSMT to provide annual bycatch estimates using the regression tree method, present a multi-year trend approach to evaluate fishery performance, and to consider how performance metrics can incentivize bycatch reduction by fishery participants.

In this report, the HMSMT provides calendar year 2017 estimates of marine mammal, turtle, and finfish bycatch and performance metrics derived from the regression tree method and details a proposed method for a multi-annual bycatch rate approach to evaluating fishery performance.

In addition, the HMSMT offers information on the statistical uncertainty surrounding bycatch estimates under different levels of DGN fishery observer coverage which the Council requested.

1. Annual Estimates of Bycatch

The Council's annual performance metrics for the DGN fishery are based on the number of specified marine mammal and turtle interactions, the number of specified finfish interactions, and an overall finfish retention rate.

Using the regression tree method, the SWFSC produces estimates for marine mammal and turtle bycatch in the DGN fishery on an annual schedule with a two-year lag, reflecting data availability and the time needed to generate bycatch models and produce the estimates (Carretta *et al*. 2019). In June 2018, the HMSMT reported estimates for the 2016 calendar year. Table 1 provides the metrics and estimates for 2016 as well as updated metrics and new estimates for 2017. The performance metric values for 2017 differ from 2016 values because they are based on a more recent bycatch publication (Carretta *et al*. 2019) that uses an additional year of DGN observer data to update bycatch estimates for previous years.

Table 1. DGN performance metrics using the regression tree method, and DGN fishery performance in 2016 and 2017 calendar years for marine mammal and turtle species for which the Council established performance metrics. Yellow highlight indicates metrics that were exceeded.

Species	Calendar Year 2016		Calendar Year 2017	
	Regression Tree Performance Metric*	Regression Tree Total Annual Bycatch Estimate	Regression Tree Performance Metric**	Regression Tree Total Annual Bycatch Estimate
Minke whale	2.3	0.3	2.8	0
Short-beaked common dolphin	57.7	28.3	62.1	33.9
Long-beaked common dolphin	5.6	5.5	5.4	2.4
Risso's dolphin	2.9	1.4	3.4	4.9
Northern right whale dolphin	8.1	8.4	10.3	5.6
Gray whale	2.1	0.5	4.1	0.2
Pacific white-sided dolphin	9.2	2.1	5.6	2.3
Sperm Whale	2.1	0	2.0	2.9
Humpback Whale	1.5	0.1	1.0	0.1
Fin Whale	0.3	0	0.3	0
Short-finned pilot whale	1.3	0.1	0.7	0
Bottlenose dolphin	4.2	0	1.5	0
Leatherback sea turtle	2.8	0	1.9	0.1
Loggerhead sea turtle	4.5	1.7	4.7	1.8
Olive ridley sea turtle	0.2	0	0.2	0
Green sea turtle	0.3	0	0.2	0

*based on highest 2004 - 2013 calendar year estimate in Carretta et al. 2018

**based on highest 2004 - 2013 calendar year estimate in Carretta et al. 2019

Since the SWFSC MMTD only derives estimates for non-finfish species, the regression tree method had to be adapted for use with finfish species in order to provide the estimates the Council requested. As requested by the Council, Table 2 provides regression tree derived performance metrics for calendar year 2017 for billfish, sharks, and manta rays. Estimates in Table 2 include a performance metric for 'non-swordfish billfish' which groups marlin, sailfish and spearfish species, similar to the "prohibited sharks" category, based on the highest regression tree estimates for the 10-year period 2004-2013. Additionally, a performance metric for scalloped hammerhead is not available ('NA'), due to an absence of any observed catch. The Council set the finfish retention rate performance metric at 70 percent and defined it as the total number of fish landed, divided by all landed catch and fish discarded dead/unknown. To meet this metric, NMFS observer data must show that the DGN fishery is retaining more than 70 percent of the catch. For the 2017/2018 and 2018/2019 DGN fishing seasons, the retention rates were 82 percent and 89 percent, respectively.

Table 2. DGN performance metrics using the regression tree method, and DGN fishery performance in the 2017 calendar year for finfish species for which the Council established performance metrics.

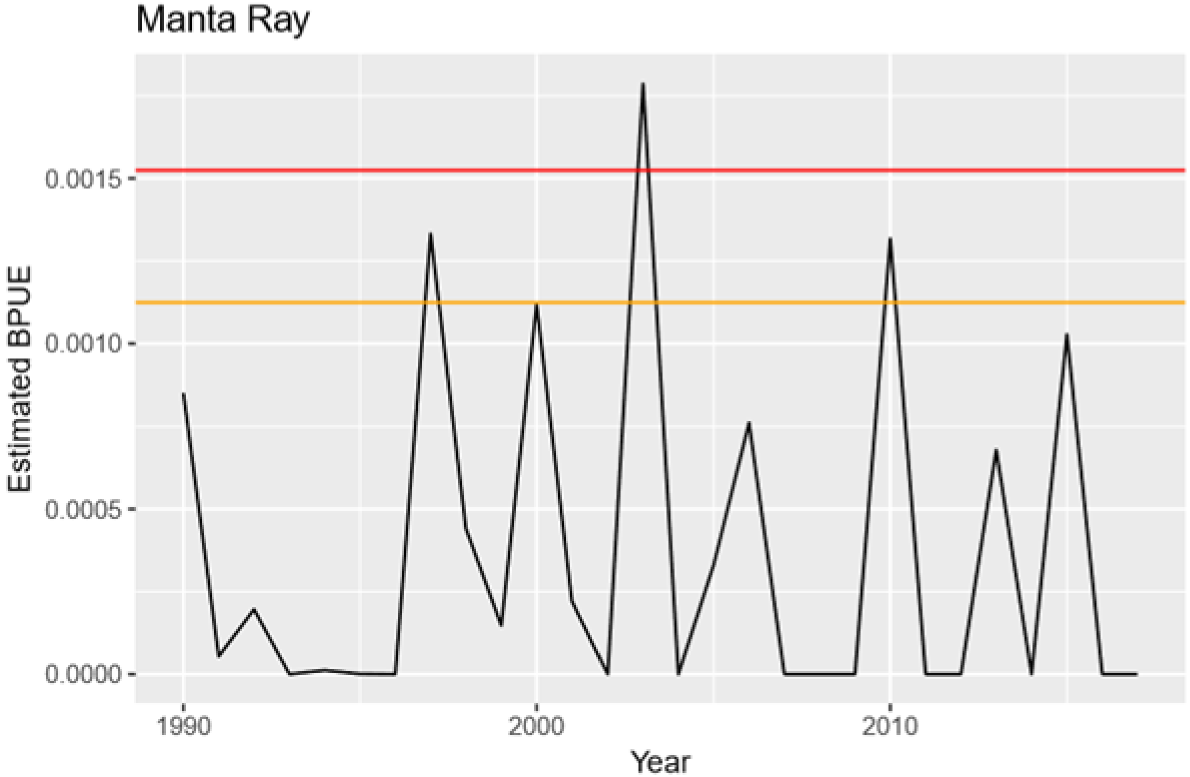
Species	Calendar Year 2017	
	Regression Tree Performance Metric	Regression Tree Total Annual Bycatch Estimate
Billfish (non-swordfish)	72.6	29.0
Prohibited sharks (megamouth, basking, white)	2.0	0.2
Scalloped hammerhead sharks	NA	0.0
Manta ray	1.3	0.0

2. Multi-annual Bycatch Rate Approach

Considering that the combination of rare-event bycatch and low observer coverage can result in volatile year-to-year bycatch estimates, the HMSMT felt that an approach which uses multi-year trends in bycatch per unit effort (BPUE), as opposed to using annual estimates of total bycatch, was more in line with the Council's desire to monitor ongoing DGN performance and a more scientifically sound approach in evaluating the fishery. However, there is still concern over exceptional events in which the estimated number of interactions with a species in a given season may be exceptionally high, and evaluating this event in the context of a multi-year trend may not lead to immediate action. To address both the need for a sound scientific basis as well as real-time fishery management concerns, in March 2019 the HMSMT described a method that translates observer data into charts displaying a time series of BPUE estimates, along with upper range limits (indicating a warning level and an action level) to identify points when BPUE is exceptionally high. An instance where these levels are exceeded in a single year can be analyzed to identify causes which may have resulted in a spike in bycatch and provide the basis for possible remedies. A more detailed description of the method and its interpretation are offered in the technical appendix at the end of this report.

Figure 1 provides an application of the proposed method to estimate annual manta ray bycatch rates. As seen in the table, the Action Line was exceeded in 2016, only; in other years, neither control line was exceeded.

Figure 1: *u*-Chart for Manta Ray *(Yellow = Warning Line; Red = Action Line)*



The HMSMT notes that exceedance of a warning or action line may reflect various factors which are unrelated to fishery performance and can be outside fishery participants' control, including temperature-driven population movement (Eguchi *et al*. 2018), random variation in the period between rare-event interactions, variation in spatial overlap between areas where market and nonmarket species are present, species misidentification, sample size variation, and close alignment of currently observed environmental variables with levels associated with past rare-event bycatch incidents. However, in the case a warning or action line is exceeded, the Council can task the HMSMT to conduct a causal analysis to determine the reason for the increase in estimated bycatch rate, as the basis for any management measures which the Council may subsequently adopt. In addition to evaluating a one-time exceedance of the action line and adopting appropriate near-term management measures to address a one-time situation which may subsequently reverse, the HMSMT recommends that the Council also consider additional longer-term management actions when the warning line for a species is exceeded in three consecutive years.

The HMSMT additionally discussed applying the proposed method to non-finfish species. The method described in the Technical Appendix assumes a random (Poisson) process for bycatch. As a result, the warning and action lines will need to be different for each species to reflect different prediction error in each case. This adjustment could avoid unnecessary action being taken due to prediction error that does not reflect the underlying bycatch. Similarly, adopting a multiyear average approach would require appropriate adjustment of the control lines.

3. Required Observer Coverage to Meet Bycatch Detection and Estimation Goals

Over the last several years, the Council has expressed interest in the relationship between observer coverage and the ability to detect/predict rare event bycatch. Until recently, no method existed by which to define this relationship. Observer coverage challenges may be broadly divided into management needs that include 1) bycatch detection, especially involving rare, endangered, or threatened species, and 2) the ability to provide a level of estimation precision that allows for meaningful management.

At times, observer coverage recommendations involve arbitrary threshold levels (*i.e.* 20 percent for common species, 50 percent for rare species; Babcock and Pikitch 2003), that may be insufficient to detect existing bycatch problems or provide adequate sample sizes to yield statistically meaningful estimates. To address the complex management needs across diverse fisheries with varying bycatch rates, a new tool (*ObsCovgTools*) was developed by SWFSC staff to address observer coverage requirements for bycatch detection and estimation precision (Curtis and Coleman 2019).

This tool estimates the observer coverage level required to calculate, first, a conditional probability of observing *any* bycatch, given that it occurred in a fishery. Secondly, the tool calculates the estimated precision of bycatch estimates at varying observer coverage levels. The precision of bycatch estimates is typically given in units called the 'coefficient of variation' (CV), a standardized measure of relative variation. A third byproduct of the tool is that given any level of fishing effort input by the user, the probability of *any* bycatch having occurred in that amount of fishing effort (observed or unobserved) is also estimated.

Observer Coverage Tool Application Example

Bycatch examples for 11 species from the DGN fishery from a variety of taxa are used to demonstrate the features and outputs of the tool. Examples are based on observer data from 2001-2017 (2,983 individual fishing sets), which represents the current management of the fishery after the Pacific Leatherback Conservation Area (PLCA) season/area closure was implemented in 2001 (Fig. 2).

Estimated total fishing effort in the DGN fishery for the most recent 10 years for which complete data are available (2008-2017) are approximately 500 to 1,000 annual fishing sets. Therefore, bycatch simulation examples use an assumed annual fishing effort of 500 sets. During 2008-2017, observer coverage has been approximately 20 percent.

Results for three species in Table 3 are also highlighted in Figures 3 - 5, representing different levels of observed BPUE for the observed fishing sets between 2001-2017. These include sperm whale, blue marlin, and striped marlin. The species chosen represent the range of BPUE values, from the extremely-rare sperm whale bycatch example (<1 animal per 1,000 fishing sets) to the more commonly caught striped marlin (26 animals per 1,000 fishing sets). This demonstrates the relative difficulties in attaining the respective goals of bycatch detection and bycatch estimate precision. Focus is on a 5-year period, representing 2,500 total sets of fishing effort, which is a suitable time period to evaluate observer coverage performance for rare-event bycatch. Evaluation of rare-event bycatch on shorter time periods (1-2 years) is likely to result in severe biases in bycatch estimation and precision (Carretta and Moore 2014).

Results of Observer Coverage Tool Example

Minimum observer coverage levels required (as a percentage of fishing effort and number of fishing sets) to detect any bycatch with an 80 percent probability are summarized for 11 example species in Table 3. Observer coverage level requirements needed to attain bycatch estimate CVs ≤ 30 percent (a threshold metric for bycatch precision) are also given in Table 2. Over a 5-year period (effort = 2,500 total fishing sets), current observer coverage of 20 percent is only sufficient to reliably detect *any* bycatch with an 80 percent probability for 3 of 11 species (northern right whale dolphin, striped marlin, and short-beaked common dolphin). The goal of attaining a bycatch estimate CV ≤ 30 percent is attainable for only 2 of 11 species (striped marlin and short-beaked common dolphin) over the same 5-year period. Increasing the observation period to 10 years (5,000 total sets fished) results in the ability to reliably detect any bycatch with an 80 percent probability for two additional species: Pacific white-sided dolphin and blue marlin, but does not result in any additional species having a bycatch estimate CV ≤ 30 percent.

For a one-year period (500 total sets fished), bycatch detection with an 80 percent probability is possible only for striped marlin and short-beaked common dolphin. It is not possible to attain a bycatch estimate CV ≤ 30 percent for any of the species summarized using a single year of fishing effort and observer data. For rarely-entangled species such as basking shark, sperm whales, and blue marlin, required observer coverage ranges between 70 percent and 80 percent of all fishing effort (360 - 400 observed sets) to reliably detect *any* bycatch with 80 percent probability with one year of data (Table 3). Increasing data availability to 5 years of fishing effort allows for 32 percent observer coverage (790 observed sets) to reliably detect blue marlin bycatch and 73 percent observer coverage (1,900 observed sets) to reliably detect basking shark bycatch.

A continuum of achievable goals that include bycatch detection and bycatch estimate CV ≤ 30 percent is evident from Figures 3-5. Three species, sperm whale, blue marlin, and striped marlin are summarized in these figures for the 5-year scenario of 2,500 total fishing sets and varying levels of observer coverage from 0 to 100 percent. Using the example of blue marlin in Figure 4a, it is evident that 32 percent observer coverage (790 observed sets) is required to reliably detect any bycatch with an 80 percent probability. If one wanted merely a 50 percent probability of detecting existing blue marlin bycatch, the level of required observer coverage drops to 14 percent (350 observed sets). Similarly, there is a continuum of observer coverage versus bycatch estimate precision that is evident in Figure 4b. An 80 percent probability of achieving a bycatch estimate CV ≤ 30 percent requires observer coverage of 81 percent (2,100 observed sets). Lowering the bycatch CV requirement to a threshold CV ≤ 50 percent requires only 55 percent observer coverage (1,400 observed sets).

4. <u>Identification of Specific Bycatch Reduction Measures</u>

The HMSMT considered the Council's request for discussion of specific bycatch reduction measures and how they may incentivize fishery participants to not exceed bycatch performance metrics. Gear modifications, time and area closures, and other bycatch mitigation measures under which the fishery currently operates have to date reduced interactions with marine mammals and sea turtles to a large degree. Further interactions may be difficult to avoid except by ceasing fishing entirely, especially in the case of rare event bycatch. Avoiding other species may require a more thorough understanding of the factors that influence their bycatch. However, the HMSMT recognizes that in certain instances additional temporary management may be necessary in order to address increased bycatch of specific species. While it is necessary to have details regarding the species and/or interactions in order to make specific recommendations which would effectively address the bycatch concern, examples of potential management measures could include seasonal time/area closures (i.e., specific areas a species is known to frequent while SST remains above a certain level), additional gear innovation and modification, incorporation of technology such as EcoCast and/or recommend the Pacific Offshore Cetacean Take Reduction Team initiate discussions.

HMSMT Recommendations:

1. Adopt the bycatch rate approach to evaluating performance metrics in the DGN fishery.
2. Task the HMSMT with providing BPUE for all species at the June 2020 meeting.

Literature Cited

Babcock, E.A. and E.K. Pikitch. 2003. How much observer coverage is enough to adequately estimate bycatch? Pew Institute for Ocean Science.

Carretta, J.V. and J.E. Moore. 2014. Recommendations for pooling annual bycatch estimates when events are rare. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-528. 11 p.

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Curtis, K.A. and H. Coleman. 2019. Observer coverage simulator (Version 2.1.1). https://kacurtis.shinyapps.io/obscov/

Eguchi, T., McClatchie, S., Wilson, C., Benson, S.R., LeRoux, R.A. and Seminoff, J.A. 2018. Loggerhead turtles (*Caretta caretta*) along the US west coast: Abundance, distribution, and anomalous warming of the North Pacific. Frontiers in Marine Science, 5, p.452.

Oakland, J.S., 2008. *Statistical process control*. Routledge.

Table 3. Minimum observer coverage levels needed to meet bycatch estimation goals of 1) achieving an 80% probability of detecting bycatch (OC. ppos), and 2) attaining an estimation coefficient of variation (CV) of ≤ 30% with 80% probability (OC.cv). Results are based on recent estimates of total annual fishing effort in the California swordfish drift gillnet fishery or 500 total fishing sets. Results include a period of 'One year', 'Five years' and 'Ten years', corresponding to required observer coverage needed to meet bycatch objectives under total fishing effort scenarios of 500, 2,500, and 5,000 fishing sets. Values for 'Total Bycatch', 'BPUE', and the dispersion parameter (d) are calculated from observer data collected during 2,983 fishing sets from 2001 to 2017. BPUE is calculated as bycatch per fishing set.

				One year		Five years		Ten years	
Species	**Total bycatch**	**BPUE**	**d**	**OC.ppos % (sets)**	**OC.cv % (sets)**	**OC.ppos % (sets)**	**OC.cv % (sets)**	**OC.ppos % (sets)**	**OC.cv % (sets)**
Bottlenose Dolphin (*Tursiops truncatus*)	1	0.000335	1.0	79 (400)	91 (460)	73 (1900)	91 (2300)	63 (2300)	91 (4600)
Basking Shark (*Cetorhinus maximus*)	1	0.000335	1.0	79 (400)	91 (460)	73 (1900)	91 (2300)	63 (2300)	91 (4600)
Sperm Whale (*Physeter macrocephalus*)	2	0.00067	2.0	79 (400)	91 (460)	69 (1800)	91 (2300)	56 (2800)	91 (4600)
Leatherback Sea Turtle (*Dermochelys coriacea*)	2	0.00067	1.0	78 (390)	91 (460)	63 (1600)	91 (2300)	45 (2300)	85 (4300)
Loggerhead Sea Turtle (*Caretta caretta*)	2	0.00067	1.0	78 (390)	91 (460)	63 (1600)	91 (2300)	45 (2300)	85 (4300)
Short-Finned Pilot Whale (*Globicephala macrorhynchus*)	3	0.001	1.0	76 (380)	91 (460)	53 (1400)	91 (2300)	32 (1600)	81 (4100)
Blue Marlin (*Makaira nigricans*)	6	0.002	1.0	71 (360)	91 (460)	32 (790)	81 (2100)	17 (810)	64 (3200)
Pacific White-Sided Dolphin (*Lagenorhynchus obliquidens*)	11	0.0037	1.9	67 (340)	91 (460)	25 (610)	75 (1900)	13 (620)	60 (3000)
Northern Right Whale Dolphin (*Lissodelphis borealis*)	24	0.008	1.5	45 (230)	85 (430)	9.9 (250)	53 (1400)	5.0 (250)	35 (1800)
Striped Marlin (*Kajikia audax*)	79	0.0265	1.0	13 (61)	55 (280)	2.5 (61)	19 (470)	1.3 (61)	10 (500)
Short-Beaked Common Dolphin (*Delphinus delphis*)	117	0.0392	1.5	10 (50)	53 (270)	2.0 (50)	18 (450)	1.0 (50)	9.7 (490)

Figure 2. Observed fishing set locations in the California swordfish drift gillnet fishery, 2001-2017. Shaded area represents the Pacific Leatherback Conservation Area (PLCA).

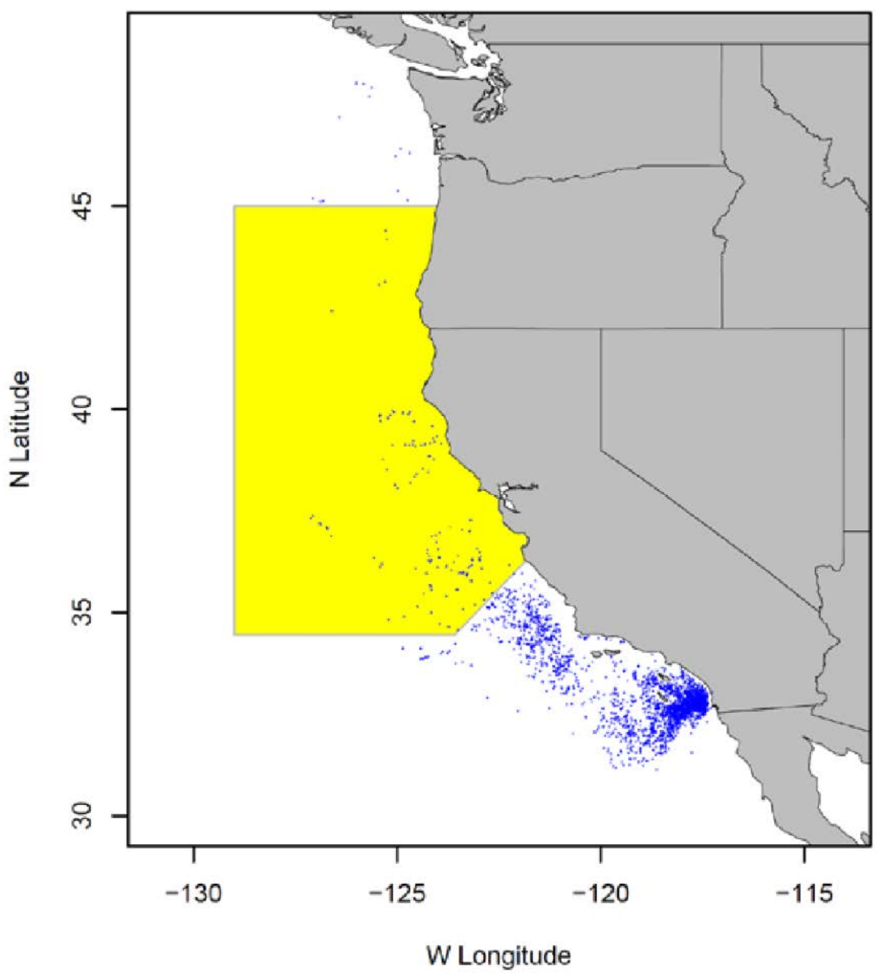


Figure 3a. Minimum observer coverage to achieve at least 80% probability of observing any **sperm whale** bycatch when total bycatch is positive is 69% (1,800 sets). The probability that any bycatch occurs in the given total effort (2,500 sets) is 69%.

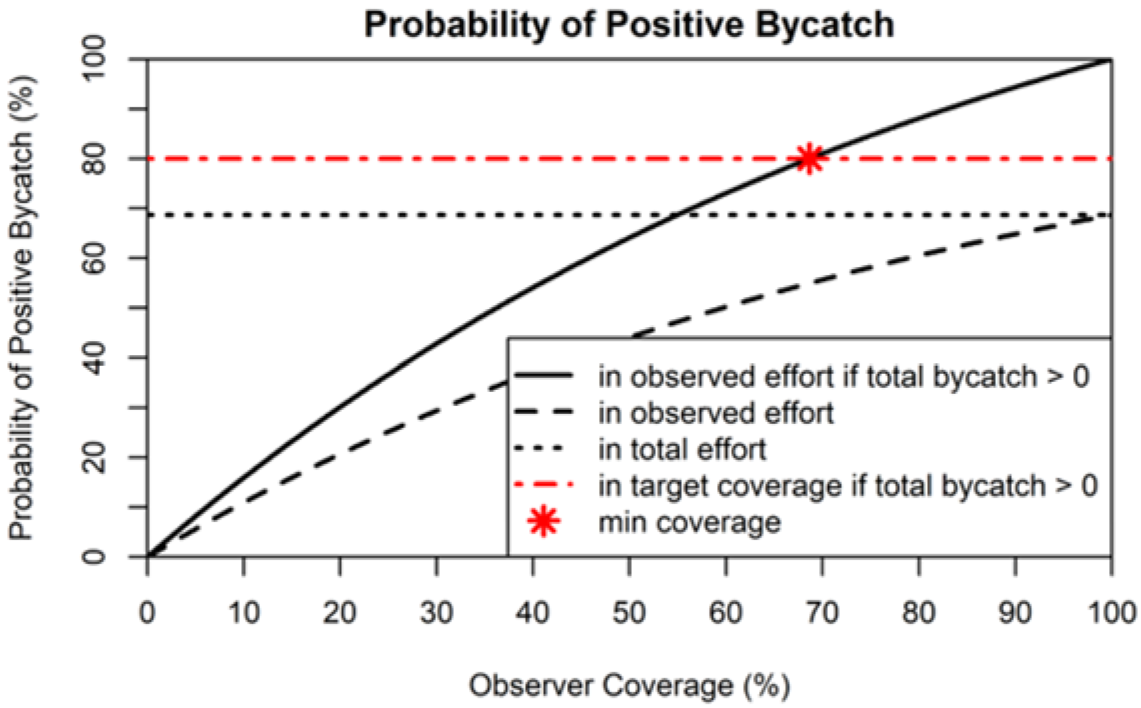


Figure 3b. Minimum observer coverage to achieve CV ≤ 0.3 with 80% probability is 91% (2,300 sets).

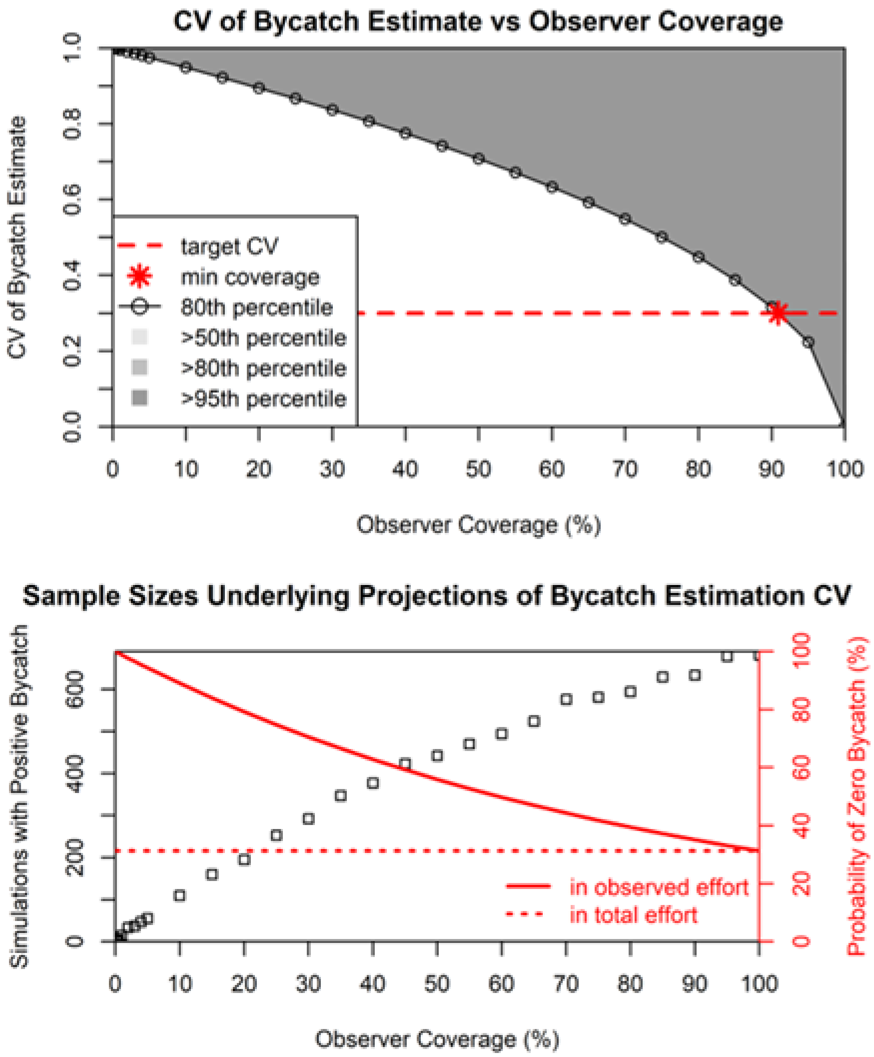


Figure 4a. Minimum observer coverage to achieve at least 80% probability of observing any **blue marlin** bycatch when total bycatch is positive is 32% (790 sets). The probability that any bycatch occurs in the given total effort (2,500 sets) is 99%.

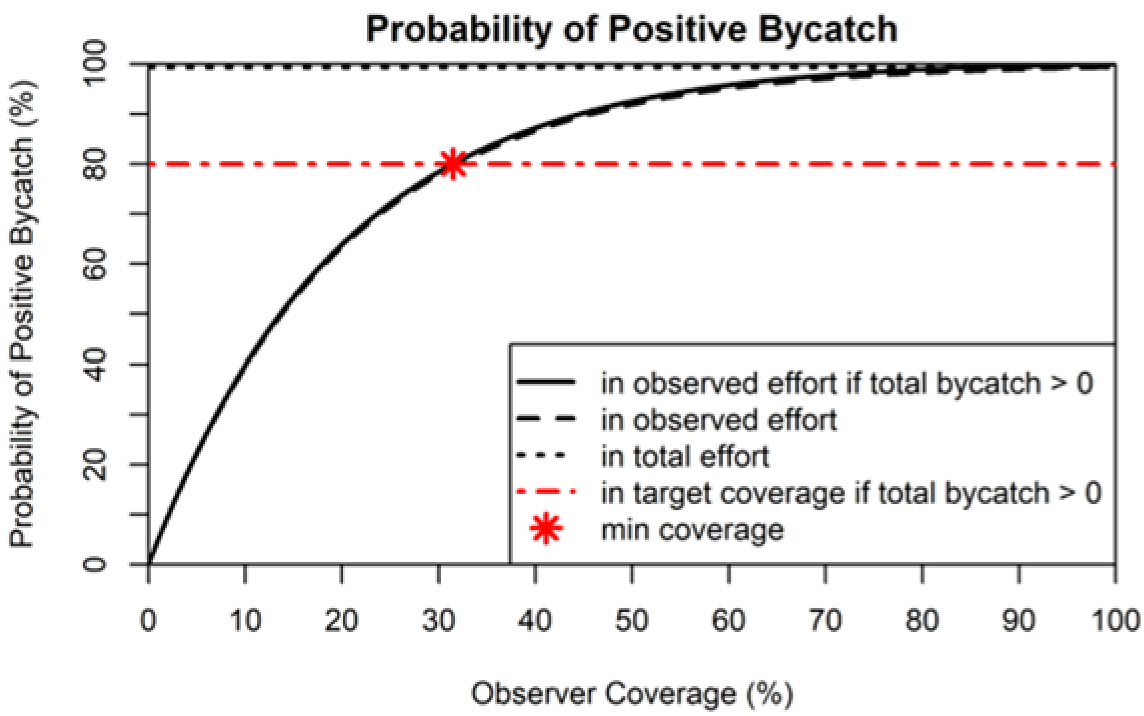


Figure 4b. Minimum observer coverage to achieve **blue marlin** bycatch CV ≤ 0.3 with 80% probability is 81% (2,100 sets).

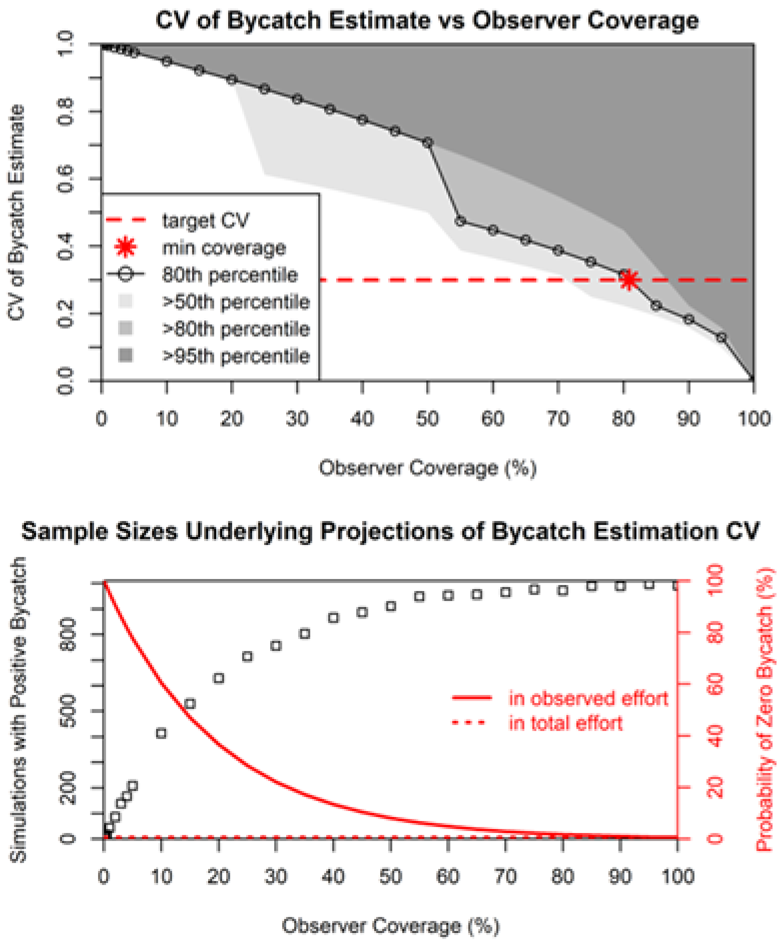


Figure 5a. Minimum observer coverage to achieve at least 80% probability of observing any **striped marlin** bycatch when total bycatch is positive is 2.5% (61 sets). The probability that any bycatch occurs in the given total effort (2,500 sets) is 100%.

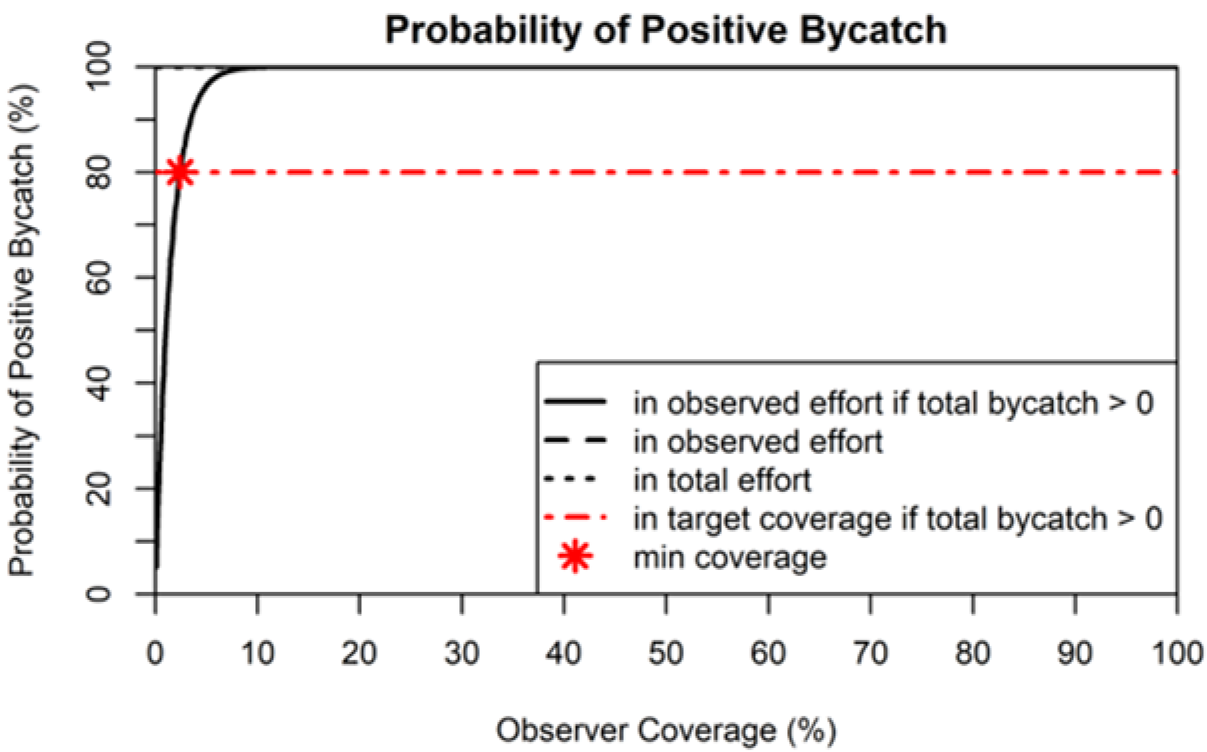
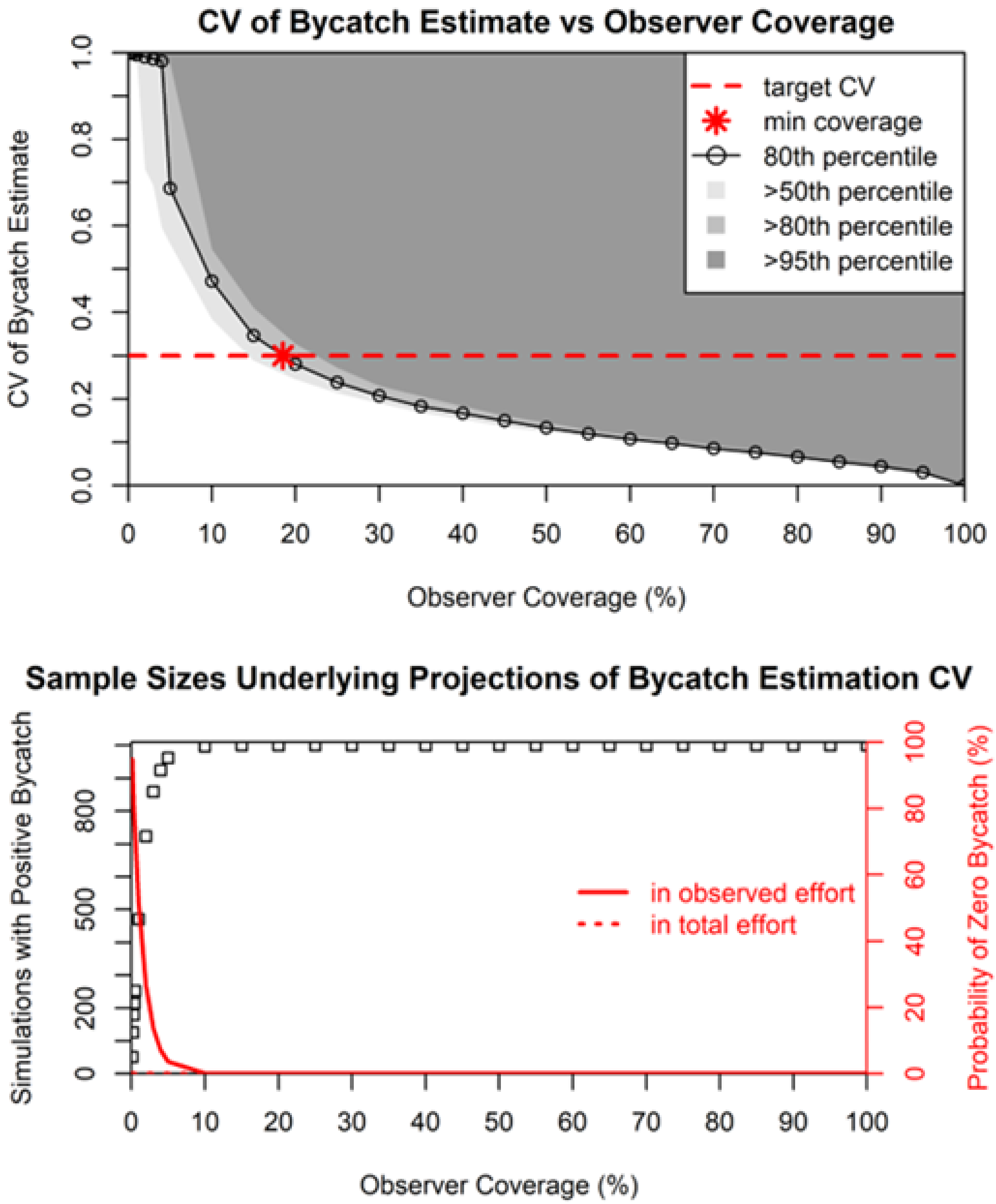


Figure 5b. Minimum observer coverage to achieve **striped marlin** bycatch CV ≤ 0.3 with 80% probability is 19% (470 sets).



TECHNICAL APPENDIX

Table 4. Model variable selection for the finfish species under the scope of the Council's request (Carretta et al. 2017).

Species	Model Variables
Black Marlin	Generic model (lat, lon, days)
Striped Marlin	lon, lat, sst
Blue Marlin	lon, lat, sst
Shortbill Spearfish	NA
Sailfish	Generic model (lat, lon, days)
Megamouth Shark	NA
Basking Shark	depth.p, soak
White Shark	Generic model (lat, lon, days)
Scalloped Hammerhead Shark	NA
Manta Ray	sst

Bycatch Rate Estimation

Carretta and Moore (2014) note that rare event counts over short time horizons (i.e. <5 years) may be unrepresentative of long-term trends in bycatch. Many of the bycatch species subject to performance metrics occur as rare events. Hence the HMSMT recommends adopting a method which recognizes that variation in bycatch counts over short time horizons may reflect random factors which are unrepresentative of fishery performance.

One possible approach to consider random variation in annual bycatch counts is to adapt a *u*-chart method described in the statistical process control literature for monitoring the number of defects or non-conformities in a manufacturing process (Oakland 2008). This approach is appropriate for situations where the number of events can be counted and reasonably be modeled as a Poisson process, and the total sample size is known. Action Lines (AL) and Warning Lines (WL) are produced to detect current bycatch rates which indicate exceedance of the normal range of variation when the bycatch process is in control. In the event that the bycatch process does not follow a Poisson distribution, one can adjust Action and Warning lines to account for the higher variability.

For application to fisheries performance metrics, we define u_i as the number of incidents per fishing sets in the current season:

$$u_i = x_i/n_i,$$

where x_i is the number of incidents and n_i is the number of sets in season i. The process average bycatch rate per unit of effort is defined as

$$\bar{u} = \frac{\sum_{i=1}^{k} x_i}{\sum_{i=1}^{k} n_i}$$

where k is the total number of seasons for which bycatch counts and numbers of sets are estimated. Action Lines (AL) and Warning Lines (WL) are defined by

$$AL = \bar{u} \pm 3\sqrt{\bar{u}}/\sqrt{\bar{n}}.$$

$$WL = \bar{u} \pm 2\sqrt{\bar{u}}/\sqrt{\bar{n}}.$$

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